Resonant Cavity Blue Light Emitting Diode

M. Diagne, Y.K. Song, H. Zhou, A.V. Nurmikko[1], R.P. Schneider[2] and T. Tetsuya[3]

[1]Division of Engineering, Brown University, Providence, RI USA 02912

[2]Agilent Laboratories, Palo Alto, CA 94303, USA

Arto_Nurmikko@brown.edu

Advances in nitride-based blue and violet light emitters, most notably high efficiency LEDs and edge emitting diode lasers, now suggest possibilities for more advanced geometries such as those based on vertical cavity structures. Within the past year, optical pumping experiments have purported to show vertical cavity lasing from InGaN MQW structures encased by as-grown GaN/AlGaN and dielectric Bragg reflectors (DBR) forming the microcavity [1]. The use of lift-off methods to separate the InGaN MQW heterostructure from its sapphire substrate has been exploited by us to achieve quasi-cw optically pumped lasing in structures equipped by two dielectric DBRs [2], at excitation levels comparable to the equivalent current injection in a good edge emitting diode laser.

While this progress is encouraging, major hurdles exist for realizing a blue vertical cavity diode laser. Apart from the requirements of a low loss, high Q-factor microcavity, the current injection into the optically active volume is difficult due to the insulating or high resistivity nature of the DBRs. We report here new advances, where the particularly acute problem of low lateral conductivity in p-GaN layers is ameliorated by the use of low-loss indium-tin oxide as an intracavity current spreading layer. The typical resistivity of the ~1000 Å thick ITO films was 3x10^{-4} Ùcm, with single pass transmission loss less than 2% in the range of 410-450 nm. By combining this feature with special processing techniques, we have been able to fabricate resonant cavity LED devices (schematic of Fig. 1), where the optical cavity is formed by two high reflectivity (R~0.995) SiO_2/HfO_2 dielectric mirrors, deposited by ion beam techniques. Light emission efficiency from the devices is excellent and they have been operated under cw conditions up to current densities of 1 kA/cm^2 and up to 10 kA/cm^2 under pulsed excitation. Figure 2 shows an emission spectrum displaying the well defined cavity modes. The measured modal half-width is approximately 0.7nm, corresponding to a cavity Q-factor of nearly 1000. The results suggest the intracavity optical losses are quite low, including contribution by the ITO layer. Furthermore, special emphasis was placed in reducing residual optical scattering/absorption losses by optimizing the morphology of the nitride

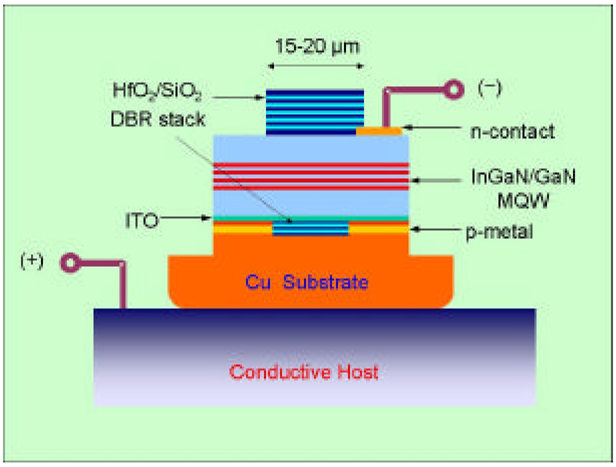

Fig. 1: Schematic of RCLED device

heterostructure during growth.

Fig. 3 shows an example of the I-V characteristics of an RCLED device, where the impact of ITO is compared with a conventional LED device with standard contact metallization. The presence of ITO does lead to a finite extra voltage drop; however, we believe that the ITO/p-GaN contact can be improved. Finally, the intensity distribution of the blue emission from the RCLED devices was quite uniform, illustrated in Fig. 4 by the photograph imaging this emission from a 25 ìm aperture device.

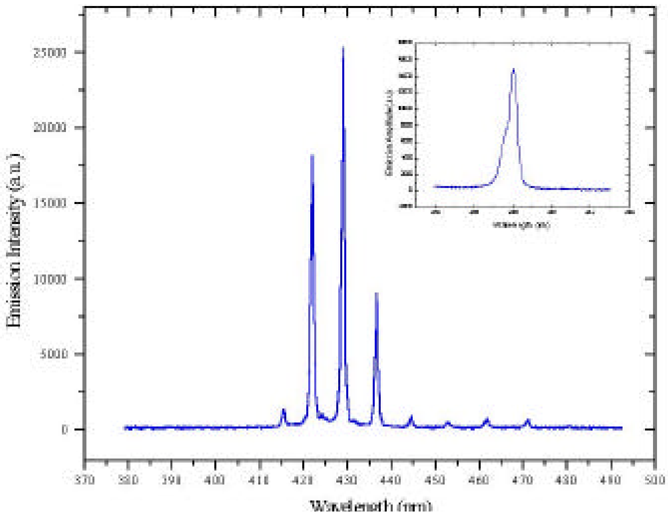

Fig. 2: Emission spectrum from the blue RCLED

These results are encouraging and suggest that further progress is likely for realizing a useful RCLED devices. The optical/electrical performance characteristics reported also indicate that a blue VCSEL may be possible through the particular technical approach used by us, which may also facilitate the study of the interesting basic microcavity physics in the nitride compounds.

[1] T. Someya et al,,Science **285,** 1905 (1999)

[2] Y.-K. Song et al, Appl. Phys. Lett. **67** , 1666 (2000)

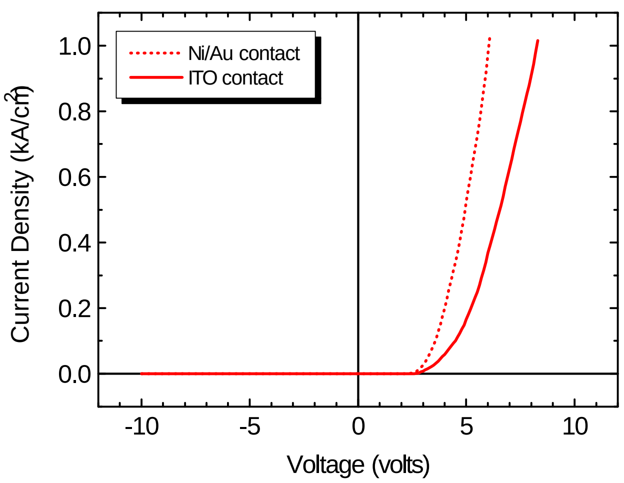

Fig. 3: IV characteristics with and without intracavity current spreading ITO layer

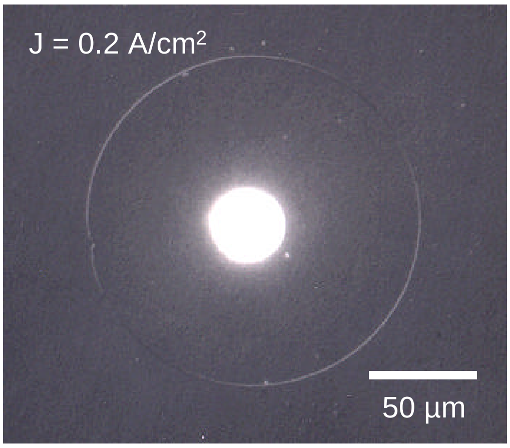

Fig 4: Photograph of blue emission from the device